Improving Campaign Assessment and Decision Making in Command and Control Through the Use of Visualisation Techniques

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At present, no adequate visualisation tool exists to support command teams in situation assessment and selection of appropriate courses of action. Research, intending to counter a gap identified between technology and the human operator, is being conducted to understand the psychological processes underlying campaign planning and situation assessment. Through a better understanding of the underlying psychological processes, it may be possible to design the most appropriate visualisation techniques to support the operators' mental models of the scenario.

Humans are very effective at representing large amounts of highly complex and multivariate information visually. Research has shown that memory for previously shown visual material is very accurate and much better than for textual material (Anderson, 1995). If incoming information is organised and linked to existing knowledge, enhanced meaning is attributed to the links. Providing visual information in a framework, as described above, will facilitate processing and comprehension (Macklin, Cook, Angus, Adams, Cook and Cooper, 2002). Visualisation technologies can aid humans in perceiving and processing information. This in turn will enhance their ability to understand, co-ordinate, share and act on information (Sands, 2000).

Visualisations have the potential to guide our perceptions of data by facilitating the identification of interrelationships. Visualisations should enable the user to interact and cope with large amounts of data. The visualisation should allow the human viewer to extract information from a vast source of information, draw conclusions and make predictions related to the command environment. The research being carried out by QinetiQ Centre for Human Sciences, aims to develop visual metaphors to support command and control tasks, with the overall objective of visualising the battlefield more effectively. By enhancing military command and control teams' situation assessment, consequent decision making and selection of appropriate actions can be facilitated.

The approach, that needs to be taken in developing appropriate visualisations for command teams, should begin with understanding how command teams make their situation assessments and how visualisations could be formulated to enhance such processes. User characteristics, decision requirements, user tasks, heuristics and circumstances of use/constraints depicting the command environment need to be considered in the proposed system/display.

In essence, visualisation is presenting information in a format that facilitates the formation of internal representations. The format of these internal frameworks can aid human cognition because they provide a visual structure that allows information and knowledge to be organised. In a complex and dynamic military setting, these can be of particular use, where comprehension of relationships among sets of

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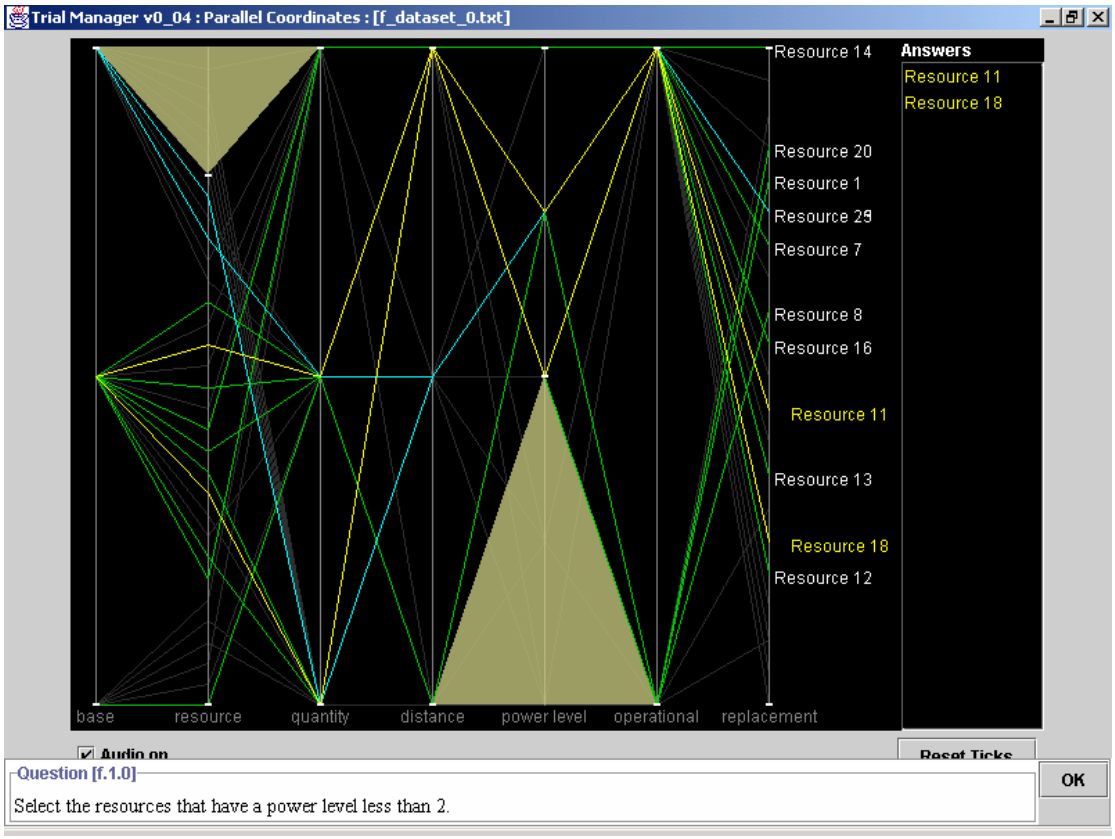
variables is crucial in order to comprehend important domain-relevant information (Goldman and Petrosino, 1999).

It is essential for newly designed techniques to successfully support users in task performance. Fundamentally, appropriately designed visualisations will only support users engaged in situation assessment and command and control that they have been designed for (Macklin and Dudfield, 2001). The design requirements for visualisation need to address the way that the proposed design will influence the social interaction across the command team. A poor or clumsy visualisation could undermine the process it aims to support. Any poorly designed visualisation tool, that robs the decision making process of cognitive resources and social process of time to communicate, will augment the conditions for failure (Macklin, Cook, Angus, Adams, Cook and Cooper, 2002).

To find out what information and cues are needed to support naturalistic decision making in a complex, dynamic environment, it is essential to develop an understanding of how operational staff, actually make decisions. This can be achieved through conducting Critical Decision Method (CDM) interviews with military personnel. Researchers (Cook and Cooper, 2001) used this approach in a cognitive task analysis exercise and responses were coded using a framework adapted from one developed for previous research into socio-cognitive processes in command teams. Responses were coded into statements arranged under four higher order categories of Cognitive Factors; Social, Organisational and Role Related Factors; Contextual Factors; and Time and Resource Management Factors. The results from the qualitative analysis support the view that the visualisation process in command teams, is likely to be a socio-cognitive process along the lines identified by Vertzberger's (1998) model of military decision making.

The issues highlighted from CDM interviews provide a basis for designing a campaign visualisation tool. These in conjunction with a collection of experience-based heuristics, can be embedded into structured templates. These templates can then be used by visualisation designers as part of a formal methodology to develop effective visualisations. Drawing on empirical evidence, sets of alternative visualisations can be designed and prototyped. Each visualisation will support a particular set of tasks. The next stage of research being conducted by QinetiQ will consider how best to present such visualisations. Evaluations have been conducted on the prototypes using cognitive walkthrough techniques involving representative end- users. Observations and comments have been fed into the final stage of prototype design. Exemplar visualisations, at the current stage of development, can be seen below. It is these visualisations that will be trialed to evaluate their effectiveness as a tool for supporting situation assessment. It is anticipated that preliminary findings will be available for presentation/discussion at the Workshop in September.



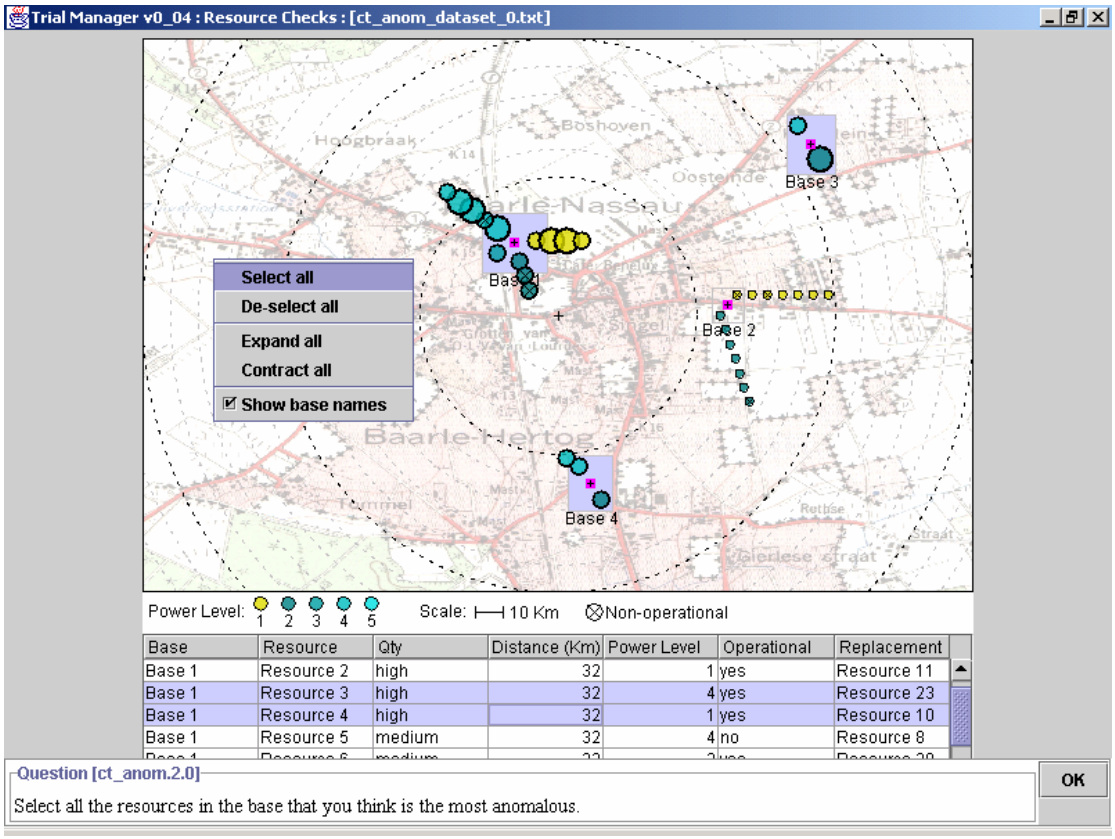
EXEMPLAR VISUALISATIONS

Parallel Co-Ordinates Visualisation

This visualisation presents a filter-based display showing several dimensions relating to the resources. Information concerning resource labels, quantity, distance, power levels, operational status and replacement options, can be displayed.

The main features of the Parallel Co-ordinates visualisation are as follows:

- Resources are shown as lines crossing discrete points on scales for each category (bases, quantity etc.).
- Categories are shown in columns which is labelled at bottom in grey (base, quantity etc.).
- All resources are labelled on right side. Resources depicted in white indicate they are unselected, once selected they become yellow.
- Category indicators can be moved up and down to eliminate/ restore resource information. Once an area has been eliminated, the area becomes shaded by grey.
- Unselected lines (resources) are shown in green. Once these are selected they become yellow in appearance.
- Resources can be highlighted. The highlighted resources are shown by blue lines.
- The visualisation has an audio function that allows a warning bleep to sound when tick marks have been correctly clicked on.

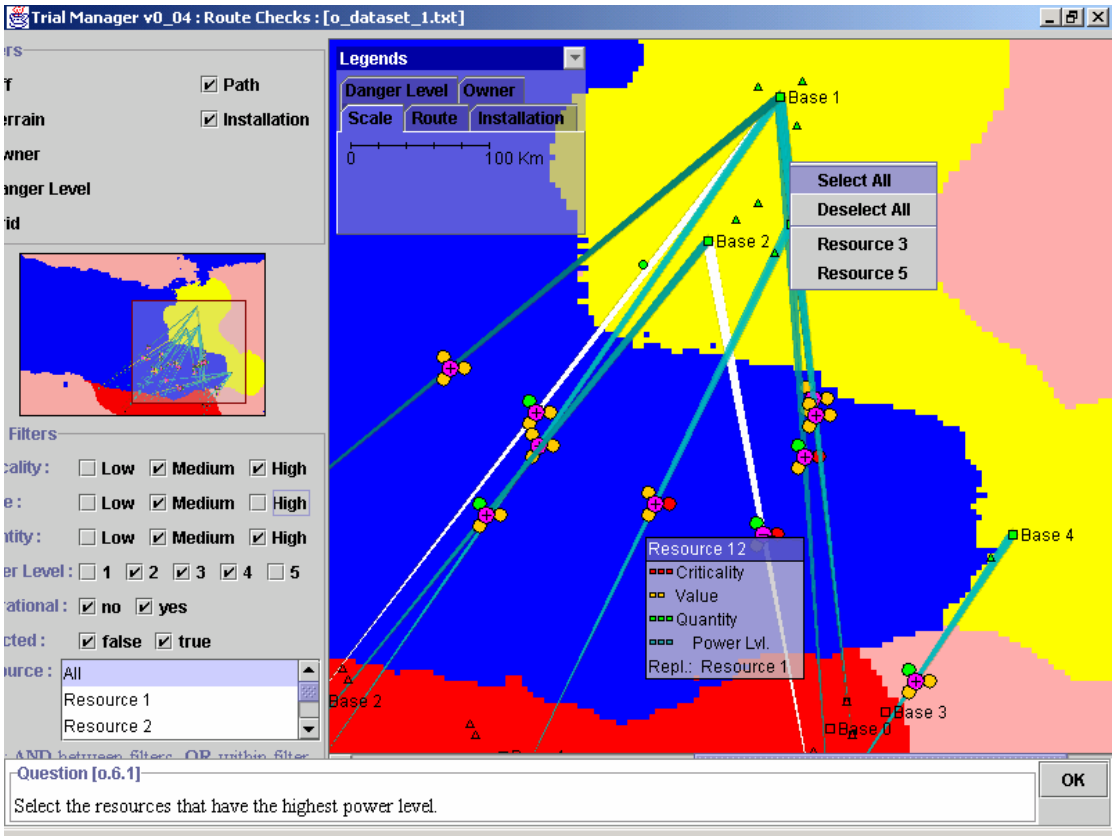


RESOURCE CHECKS VISUALISATION

This visualisation presents a map-based display showing the locations of resources at differing bases. Information is presented regarding the quantity, power level, distance and whether operational of given resources. This visualisation also has the facility of indicating replacement resources.

The main features of the Resource Checks visualisation are as follows:

- Bases are shown as clusters of circles surrounding a pink square.
- The pink square is used for expansion and contraction to show all or a few of the resources.
- Expanded bases are shown as ‘arms’ of circles radiating from the pink square.
- Each circle represents a resource.
- The actual location of base is depicted by the location of the pink square.
- Non-operational resources have a cross in the circle.
- The size of circle represents quantity of the resource.
- Power levels of circles are represented by colour code.
- When resources are selected the information appears in a table below.



ROUTE CHECKS VISUALISATION

This visualisation presents a map-based display showing the routes that resources take from different types of friendly bases to enemy bases. Information is presented regarding the value, criticality, quantity, power level and whether operational. There is also the option of showing different backgrounds such as terrain, danger level and ownership.

The main features of the Route Checks visualisation are as follows:

- Base numbers are shown on the map.
- A Legends panel, shows five sets of information on Danger Level, Owner, Scale, Route and Installation.
- A Danger level legend is shown by display danger in varying colours. These are as follows: no danger- dark green, low danger- light green, medium danger- yellow, high danger- orange, very high danger- red.
- An Owner legend is displayed to indicate whether base is neutral (territory pink), enemy (red) or friendly (yellow).
- Base types are depicted using different shapes. A SAM Site is shown by a triangle, a power station is represented as a circle.
- A Route legend shows each resource as a tapered line with the colour indicating power level rated 1-5 (yellow to blue). Half way along each line is a circle cluster showing quantity, value and criticality of resource colour coded to indicate low, medium or high. At the centre of the cluster is a pink circle, which can be used to activate the pop up window.

SYMPOSIA DISCUSSION – PAPER NO: 17

Author's Name: Ms. Liz Fricker, QinetiQ, Farnborough, UK

Question:
Visualisation is a very broad multidisciplinary effort. How does this research give us guidance?

Author's Response:
This research is attempting to create guidelines as to what elements should be included in a display and where different elements fit.

Question:
How do the features of the organic displays map to the information?

Author's Response:
The legs map to the locations and the size.

Question:
Have these interfaces been presented to a command and control user group?

Author's Response:
Yes, users from across the services have been consulted. It has been an iterative interaction, with the cognitive walk through being the first stage and the "wow viz" being developed taking their comments into consideration.

Question:
How are data with different degrees of uncertainty due to the fog of war displayed?

Author's Response:
This has not been specifically addressed in this system yet.

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Improving Campaign Assessment and Decision Making in Command and Control Through the Use of Visualisation Techniques

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Introduction

- Background
- User requirements
- Prototype design
- Cognitive walkthroughs
- Experimental campaign
- Conclusions

Research objectives

- Support command teams in real time assessment of campaign through advanced dynamic visualisation techniques
  - Understand the social and cognitive processes underlying campaign planning and assessment tasks
  - Facilitate command team decision making
  - Support selection of appropriate courses of action
  - Exploit this understanding via the design of *appropriate* visualisation techniques
  - Production of guidelines to inform future visualisation design

This work was funded by the Chemical and Biological Defence and Human Sciences Domain of the MOD's Corporate Research Programme

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Why visualisations?

- Humans are very effective at understanding large amounts of data presented in a visual format
- Structured incoming information
- Identifying interrelationships
- Enhanced memory for visual information

The visualisation process

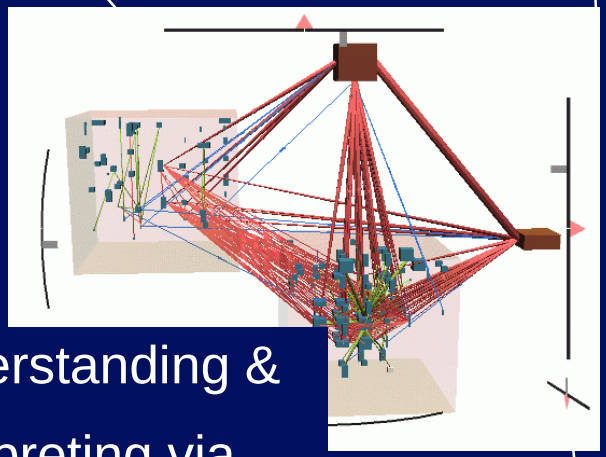
Information

Data

Data

Data

Data



Understanding &

Interpreting via

visualising

Knowledge
Decision
Action

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Identifying visualisation requirements

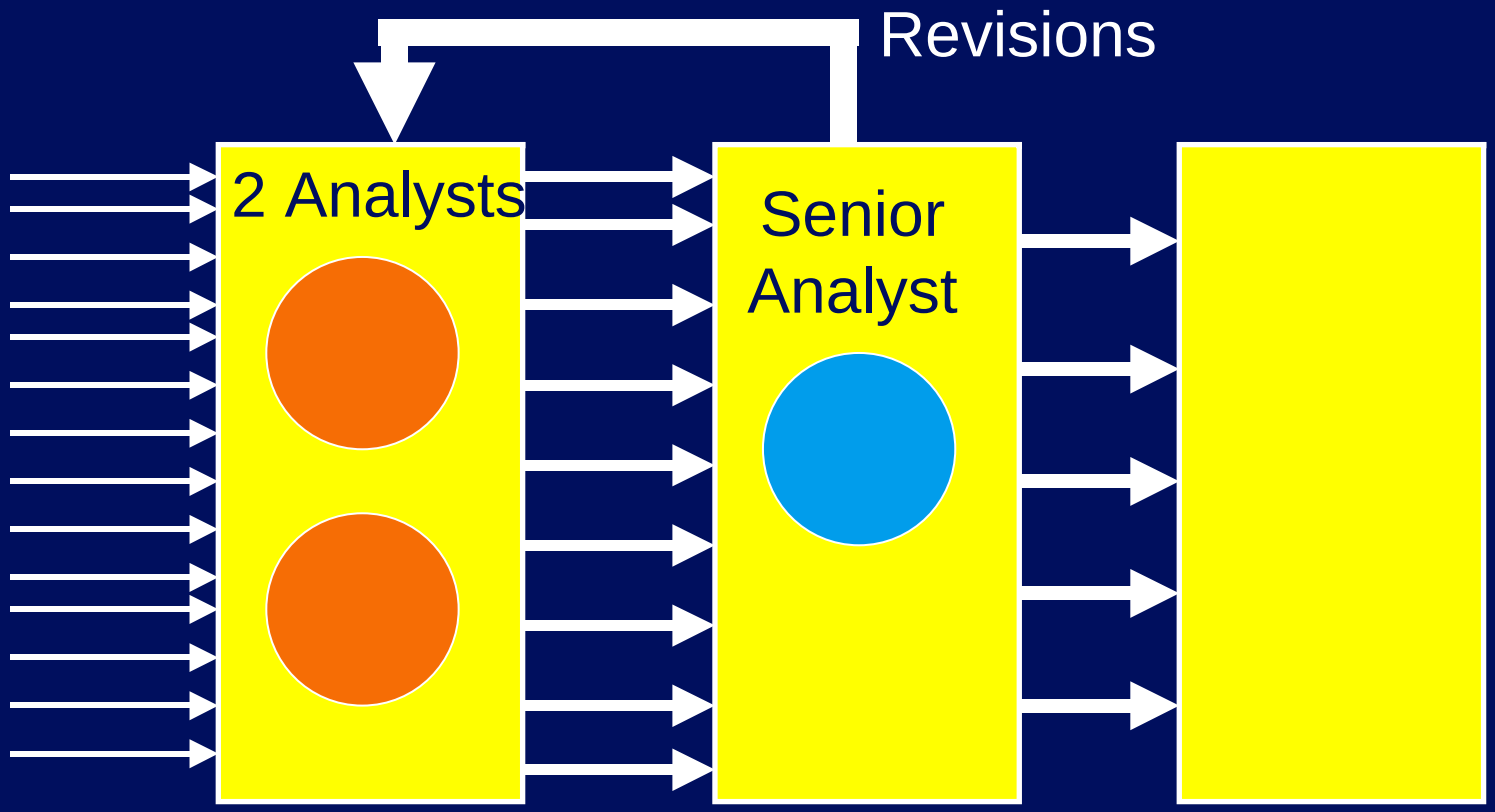
- Appropriately designed campaign visualisations will facilitate: Shorter decision cycle and optimal decision making
  - Visualisations should support user's mental models
  - Visualisations should support task performance
  - Visualisation design should consider user's decision requirements
  - Adapted Critical Decision Method (CDM) interviews based around critical command and control incidents

Critical Decision Method

- CDM Interviews:
- Recall critical incident
- Use cognitive probes to capture tacit or implicit knowledge
- Benefits:
- Captures detail in context
- Rich source of data for design - how people actually experience/perform tasks

Klein;1993, Chandler et al; 2000

Method of analysis



Sub-categories used for analysis

- Time frame
- Enemy characteristics
- Situation awareness
- Environmental
- Hierarchy
- Information and knowledge
- Gut instinct (implicit cognition)
- Co-ordination
- Behavioural factors
- Team and group factors
- Display and technology (perceptual issues)
- Communication
- Organisational factors
- Decision making
- Factors in warfare
- Psychological processes

Results: higher order categories

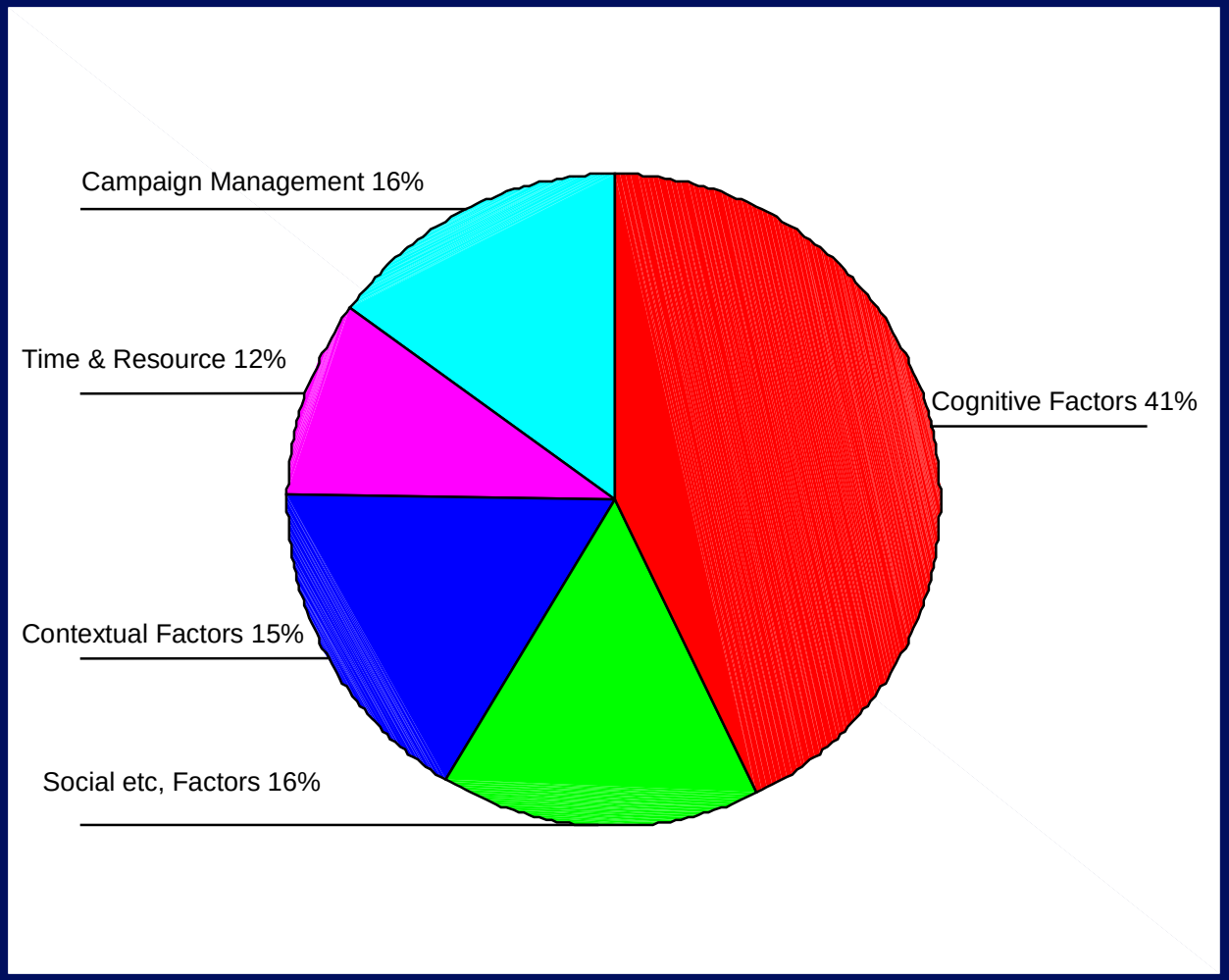
- Cognitive
  - Decision-making, information and knowledge, situational awareness, gut instinct, display and technology
- Social
  - Hierarchy, organisational, team and group factors, behavioural factors, communication

Macklin, Cook, Angus, Adams, Cook, Cooper; 2002

Higher order categories continued

- Contextual
- Time and resource
- Campaign Management
- Enemy characteristics, environmental, factors in warfare
- Co-ordination and time frame
- Remaining factors related to military protocols (initially coded under sub categories) but not falling directly under higher order categories

Higher order category representation



Macklin, Cook, Angus, Adams, Cook, Cooper; 2002

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Prototype design

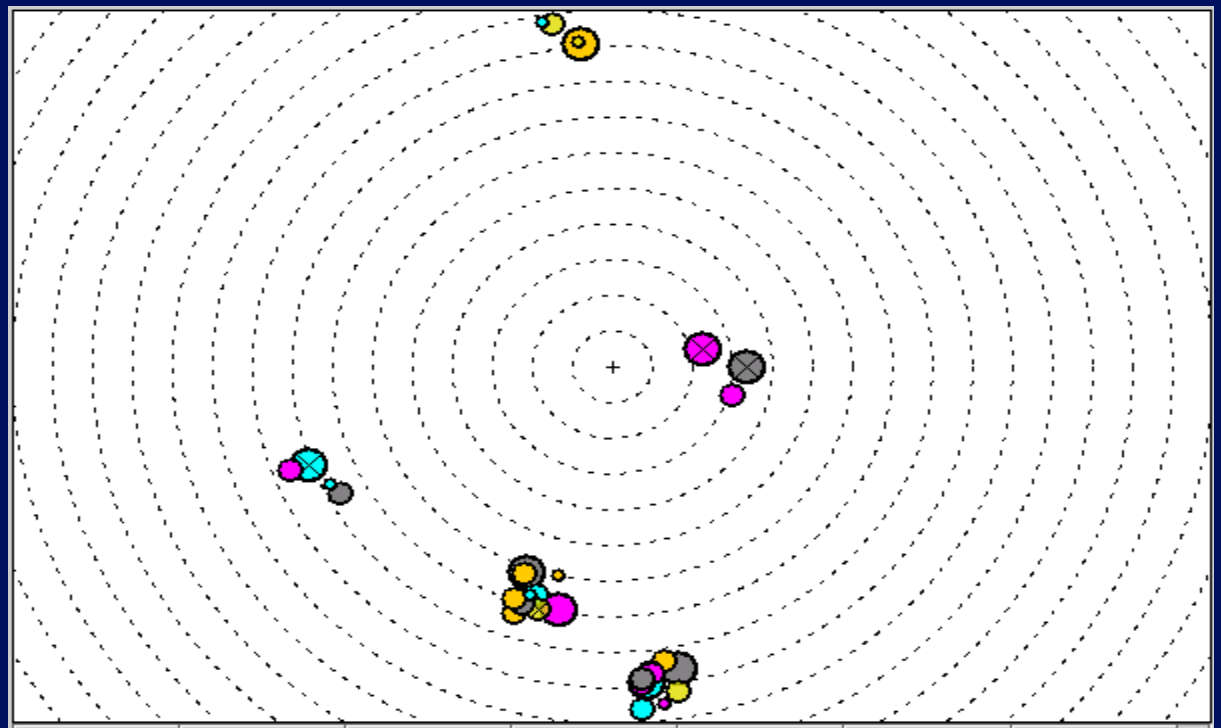
- Visualisations must support cognitive and social processes of command teams
- Issues from CDM interviews provide basis for designing visualisations
- Experienced based heuristics
- Visualisations supporting sets of tasks

Cognitive walkthrough

- Visualisation prototypes evaluated with representative end users.
- Verbal protocol
- Identifies problems with software (design faults), tasks (realism) and visualisations (usability)
- Identifies suitability for future empirical evaluation

Cognitive walkthrough

- 6 Visualisation formats were evaluated:
- Resource checks
- Route checks
- Parallel co-ordinates
- Organix
- Mission execution
- Mission dependencies



Base	Resource	Qty	Distance (Km)	Power Level	Operational	Replacement
Base 1	Resource 7	medium	65	5	yes	Resource 9
Base 1	Resource 10	medium	65	5	yes	Resource 7
Base 2	Resource 14	medium	80	3	yes	Resource 18
Base 2	Resource 15	medium	80	4	yes	Resource 9
Base 3	Resource 17	medium	116	1	yes	Resource 19
Base 4	Resource 20	medium	116	5	yes	Resource 11
Base 4	Resource 21	medium	116	1	yes	Resource 3
Base 4	Resource 22	medium	116	1	yes	Resource 31

Resource checks

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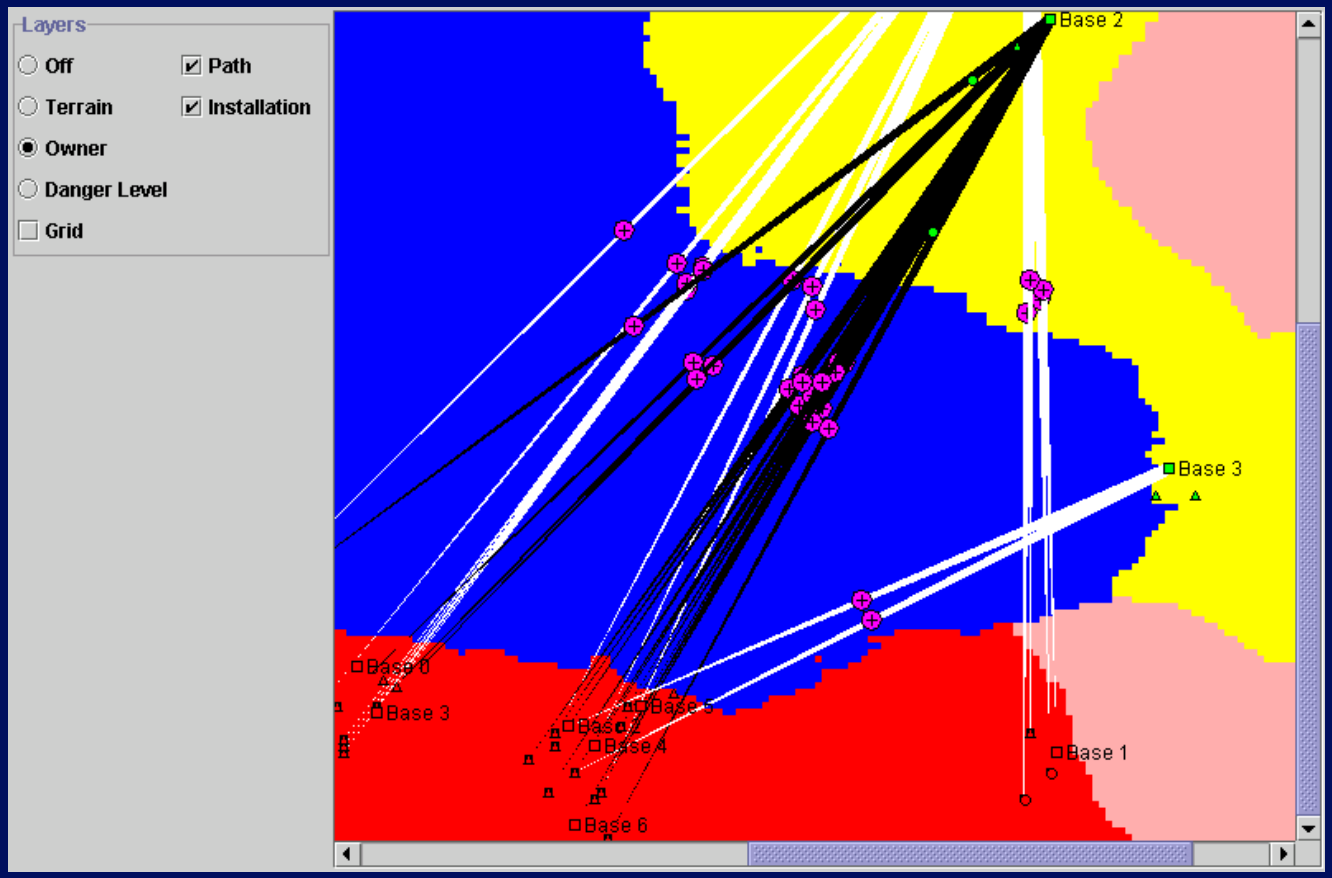

Route checks

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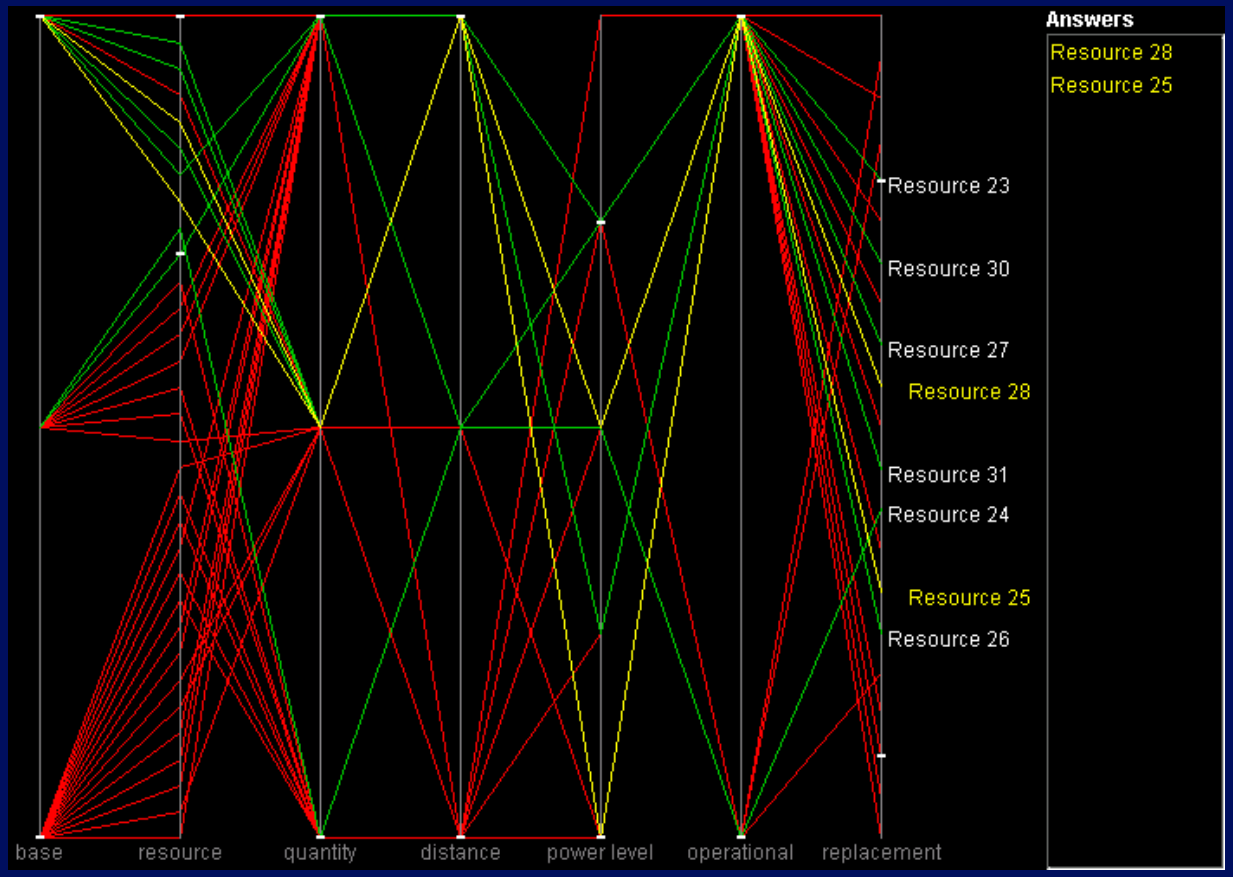

Parallel co-ordinates

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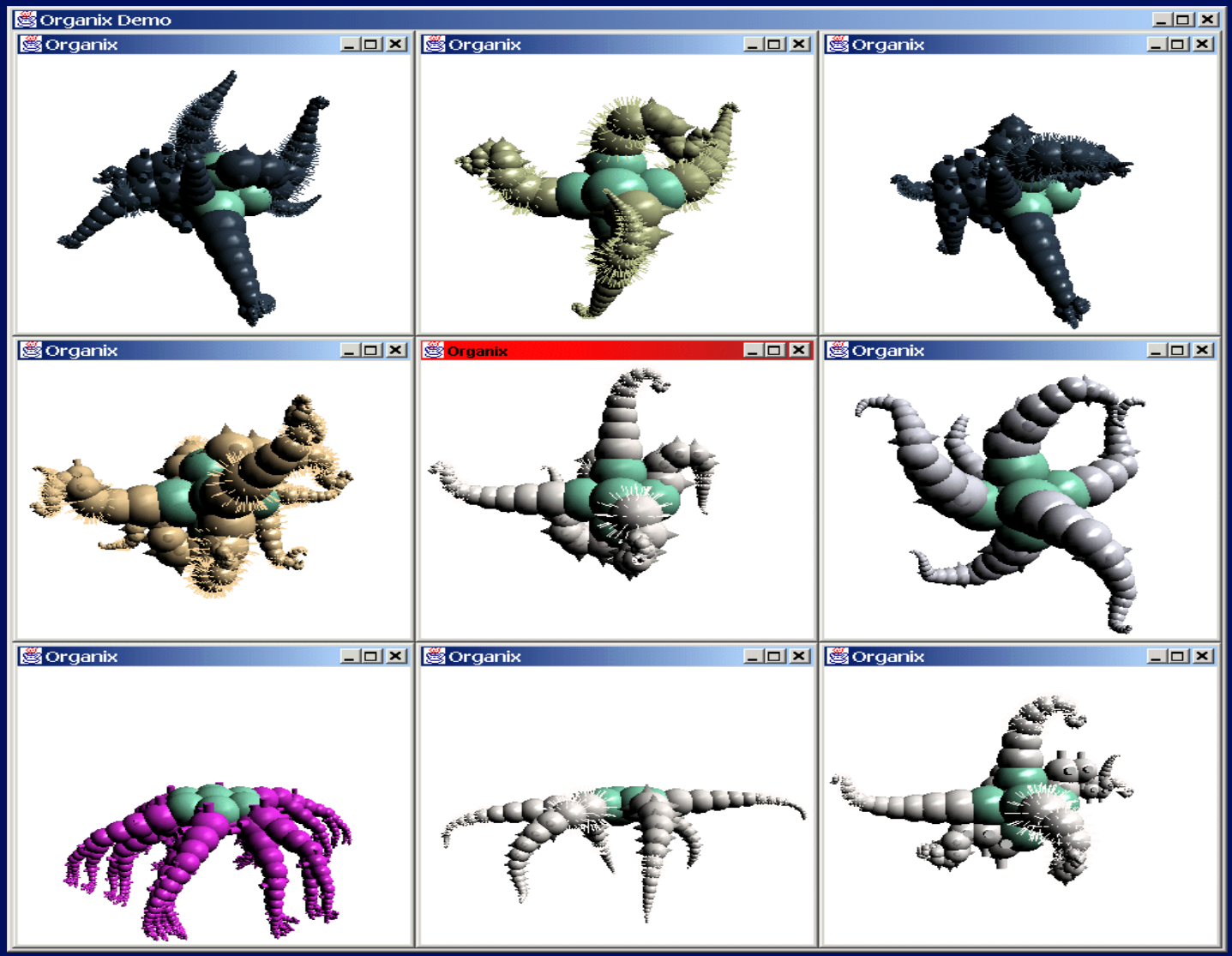

Organix

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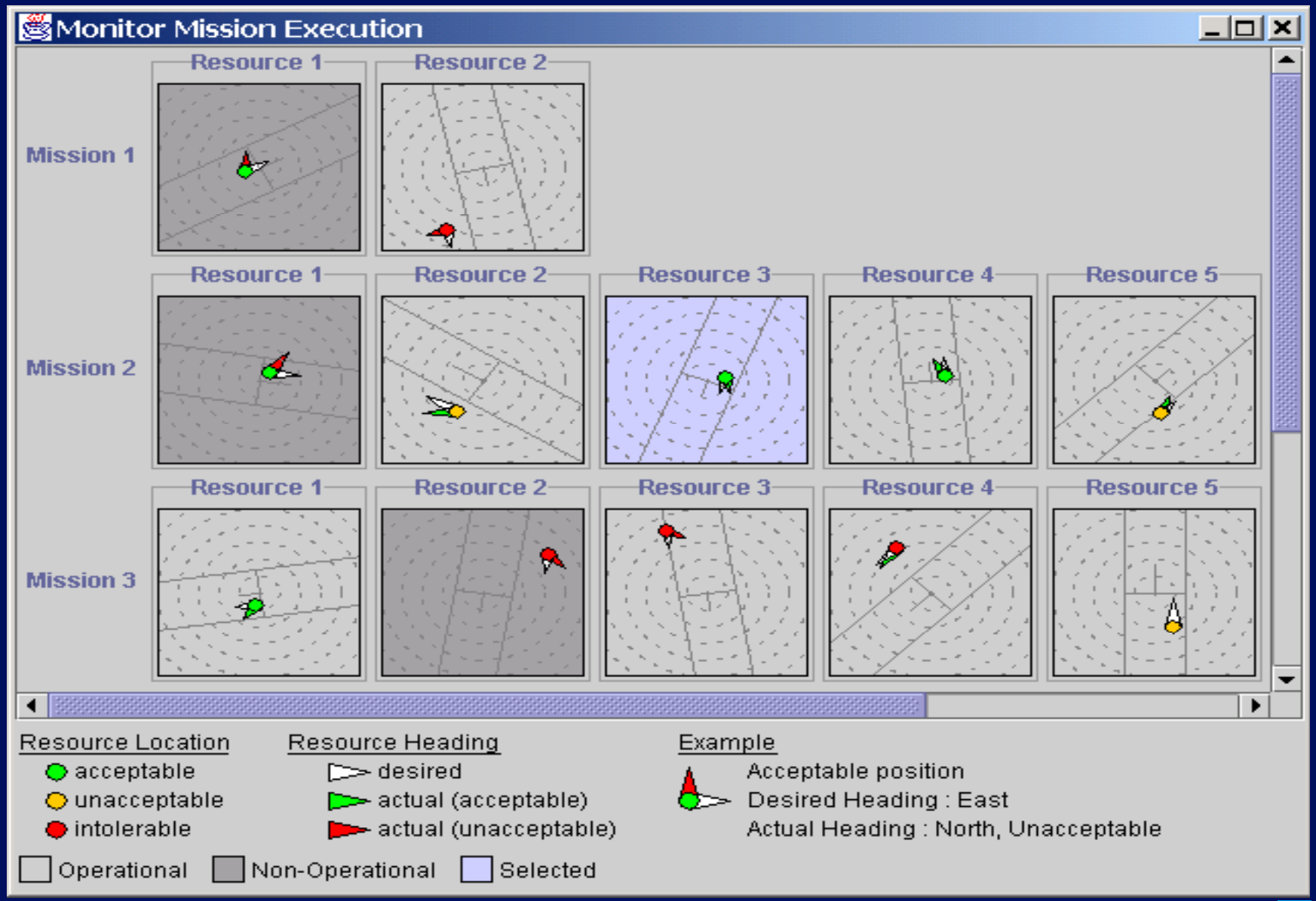
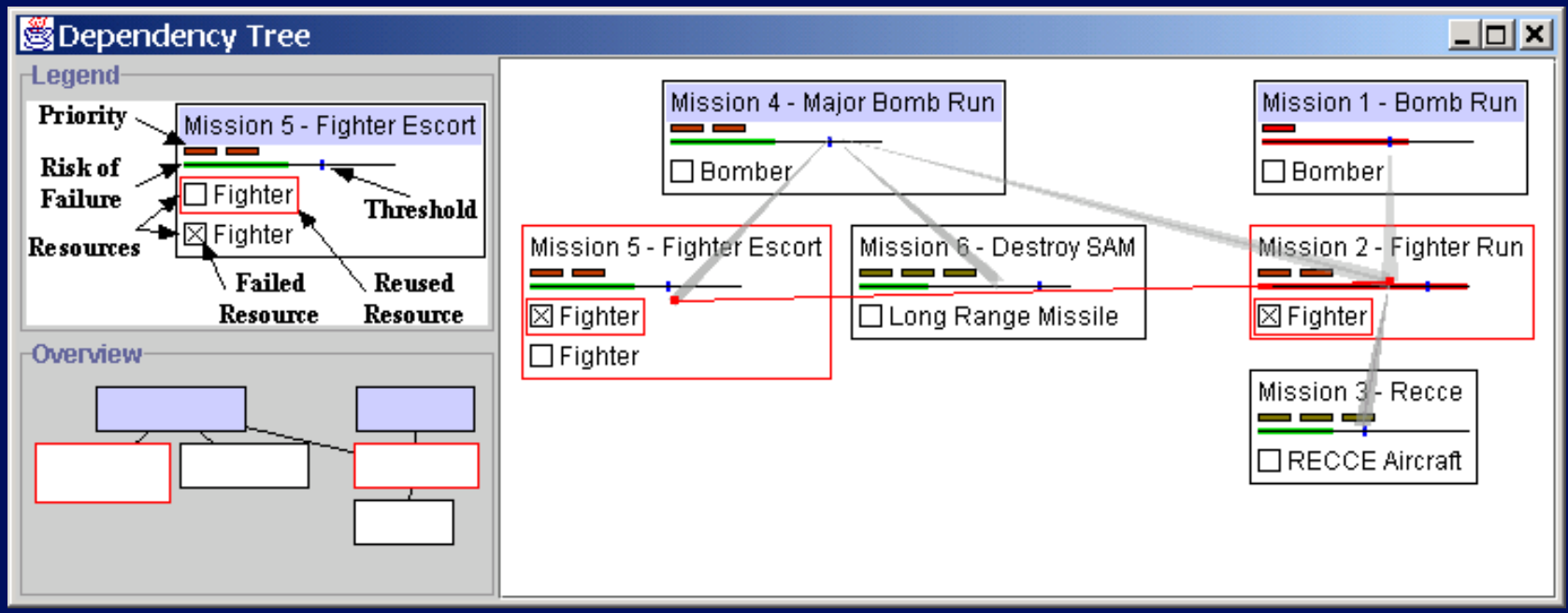


Mission execution



Mission dependencies

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Results

- Usability
  - Global score = 73 %
- Rated intuitiveness
  - Route checks, Parallel co-ordinates, Organix
- Rated preference
  - Route checks, Parallel co-ordinates, Resource checks

Experimental campaign

- 2 phases
- Experiment 1 = choosing ‘the best visualisation’
- Experiment 2 = visualisations compared to databases and graphs

Experimental tasks

- Simple task
- *Find, Look-up, Optima*
- e.g. ‘select the resources with a power level less than 3’
- Complex task
- *Data exploration*
- e.g. ‘considering the relationship between base 0 and 1, which of the other bases are most similar?’

Salisbury; 2001

Experimental measures

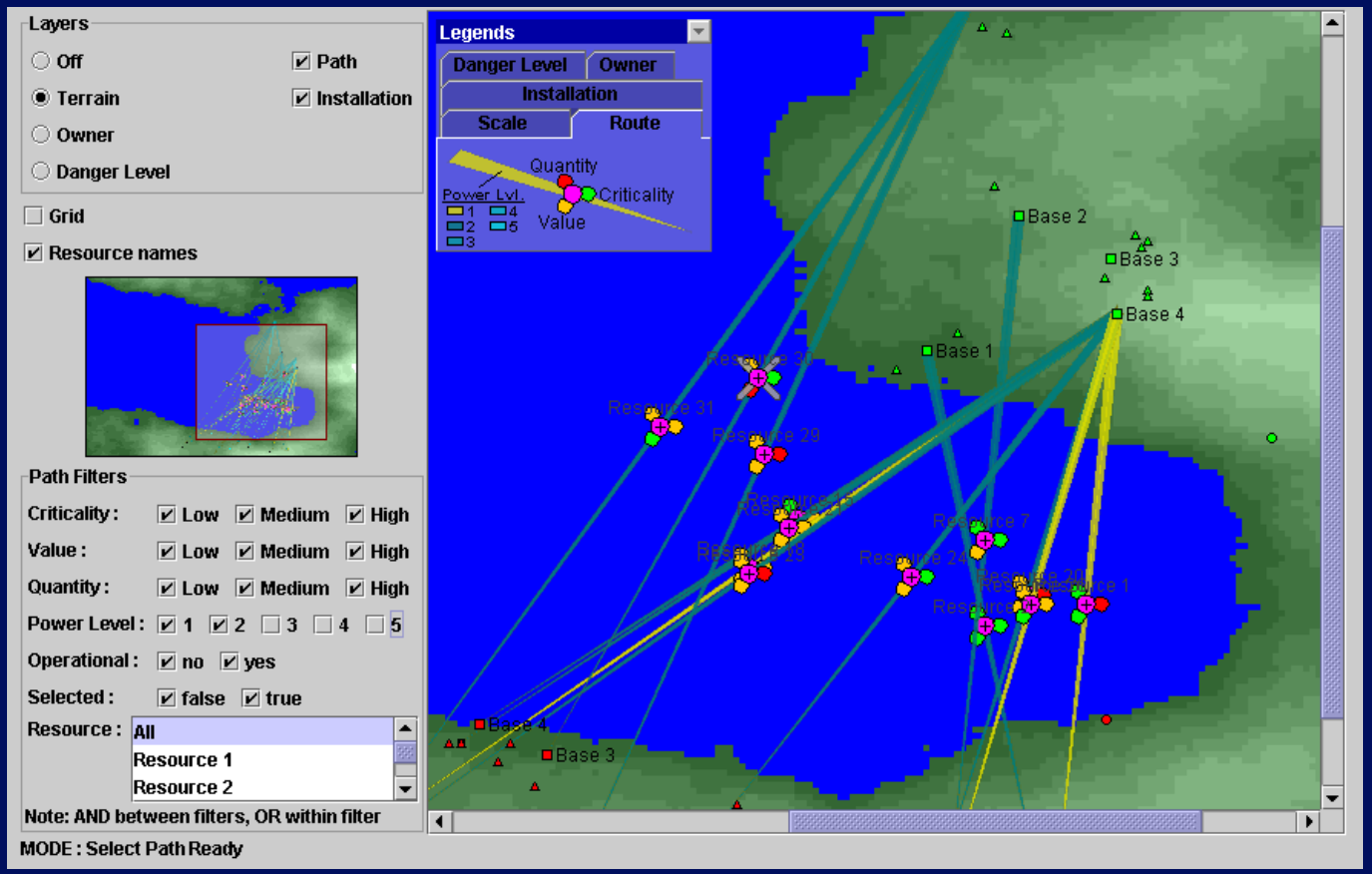
- Reaction times
- Accuracy
- Subjective evaluation
- Mental Model elicitation - card sorting exercise
- User’s comments

Visualisation formats- experiment 1

- Both formats constructed using heuristic guidelines
- ‘Just-a-Vis’ (JV)

  Format used in CW
- ‘Wow Vis’ (W V)

  JV format + user feedback



Wow Vis Route checks

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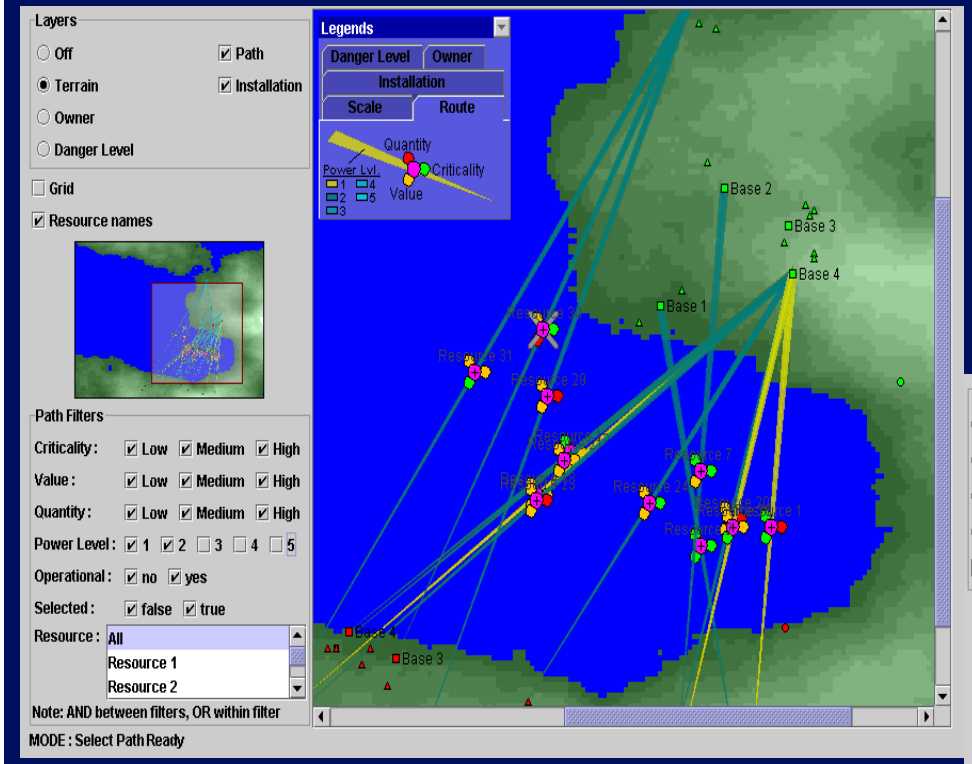
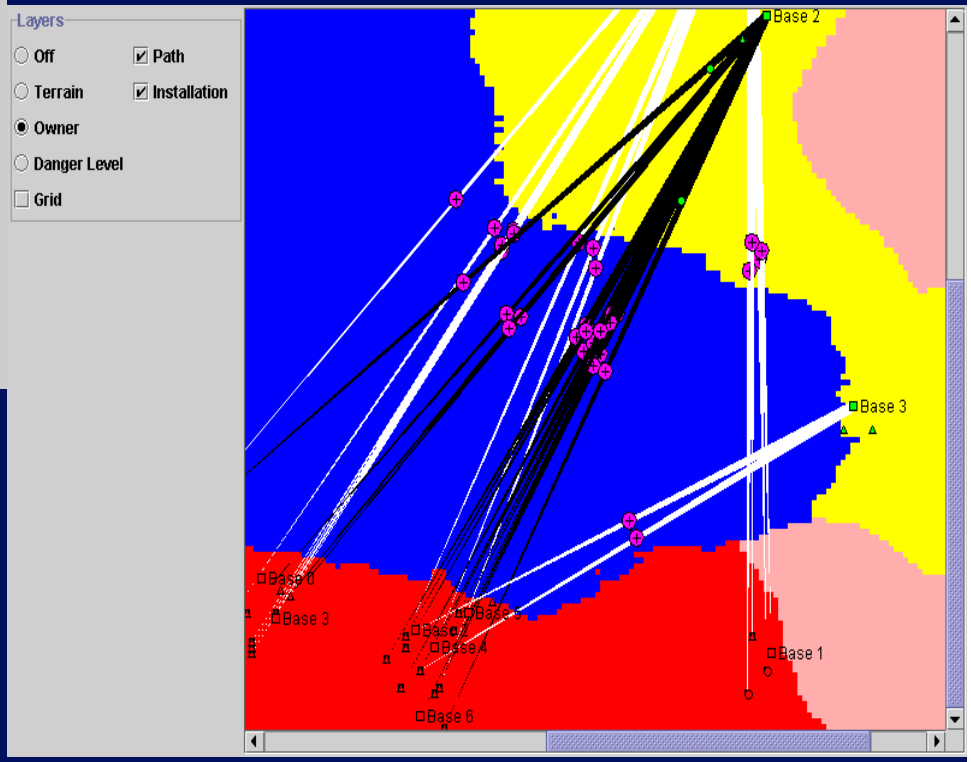
Wow Vis



Just-a-Vis



Route checks

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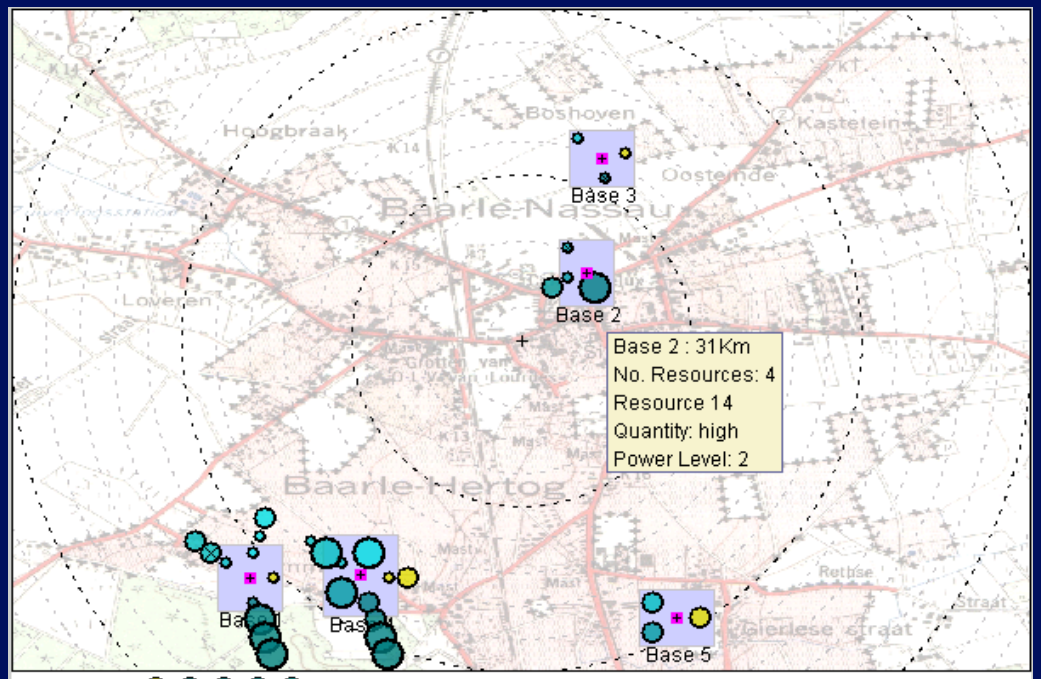

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Base 1	Resource 3	high	134	2	yes	Resource 21
Base 1	Resource 4	low	134	4	yes	Resource 18
Base 1	Resource 5	medium	134	4	no	Resource 7
Base 1	Resource 6	medium	134	4	yes	Resource 26
Base 1	Resource 7	high	134	2	yes	Resource 2
Base 1	Resource 8	low	134	5	yes	Resource 6

Wow Vis Resource checks

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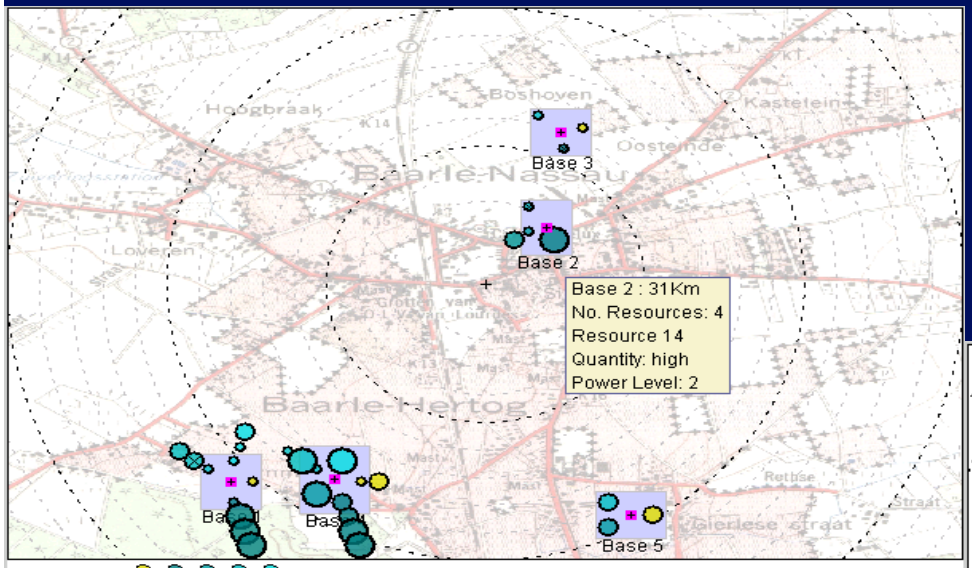
Wow Vis



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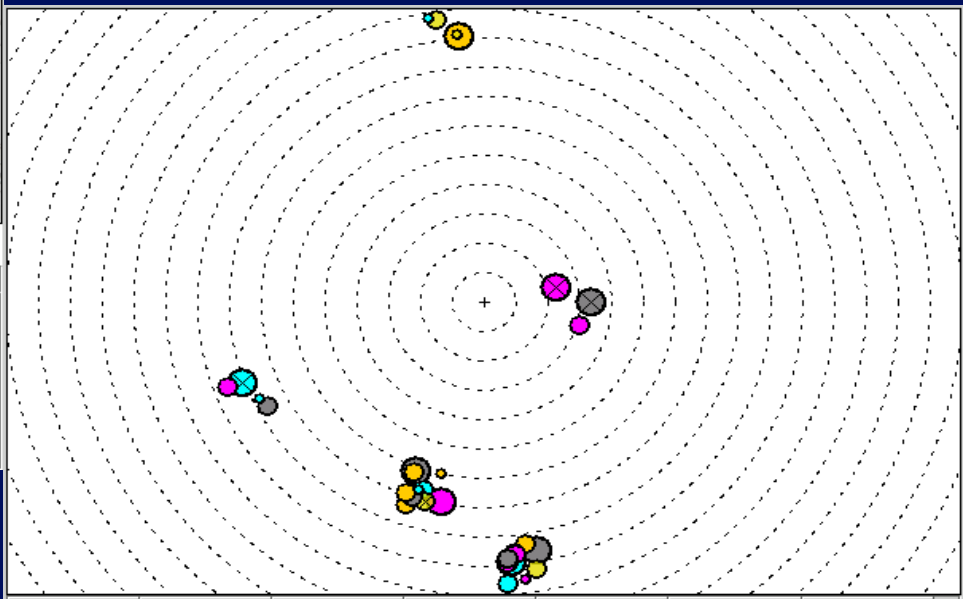
Base 1	Resource 6	medium	134	4	yes	Resource 26
Base 1	Resource 7	high	134	2	yes	Resource 2
Base 1	Resource 8	low	134	5	yes	Resource 6

Just-a-Vis



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Resource checks

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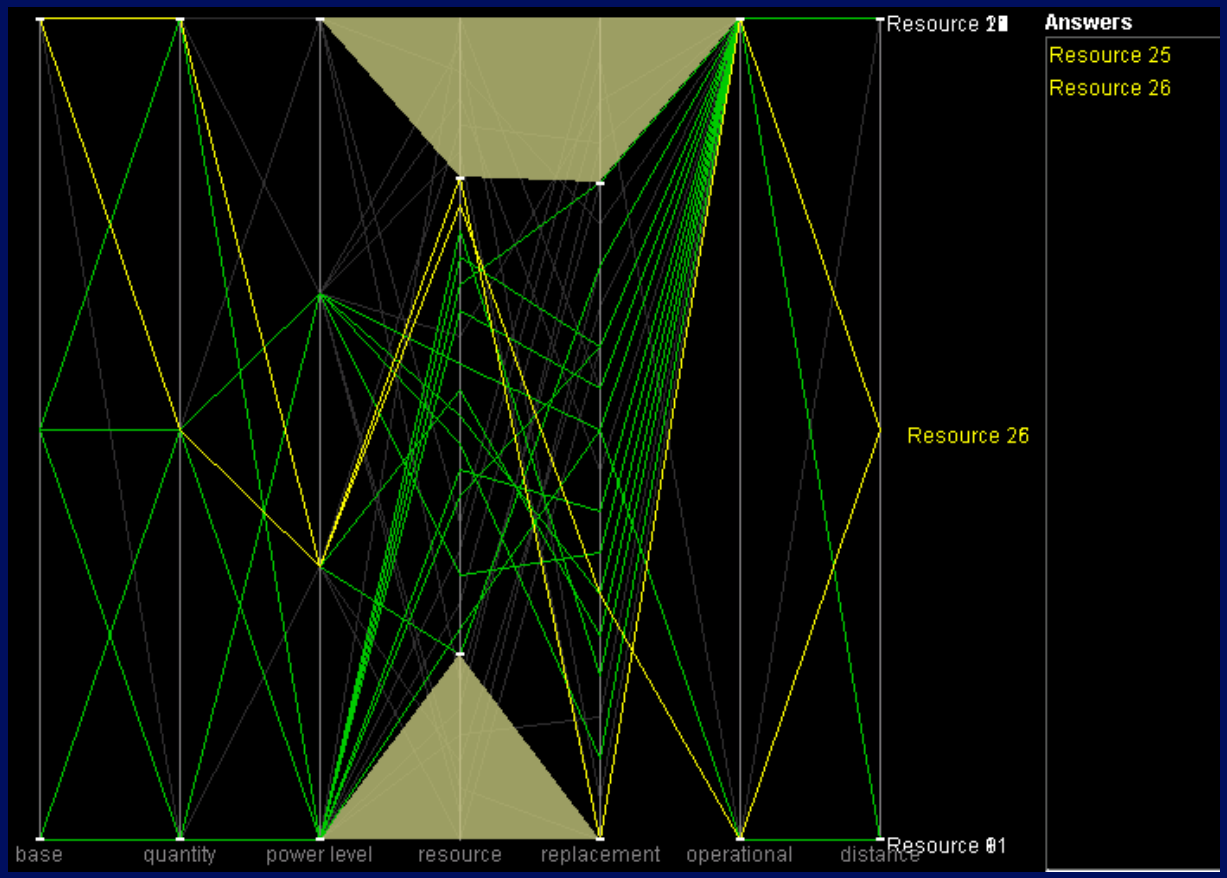

Wow Vis Parallel co-ordinates

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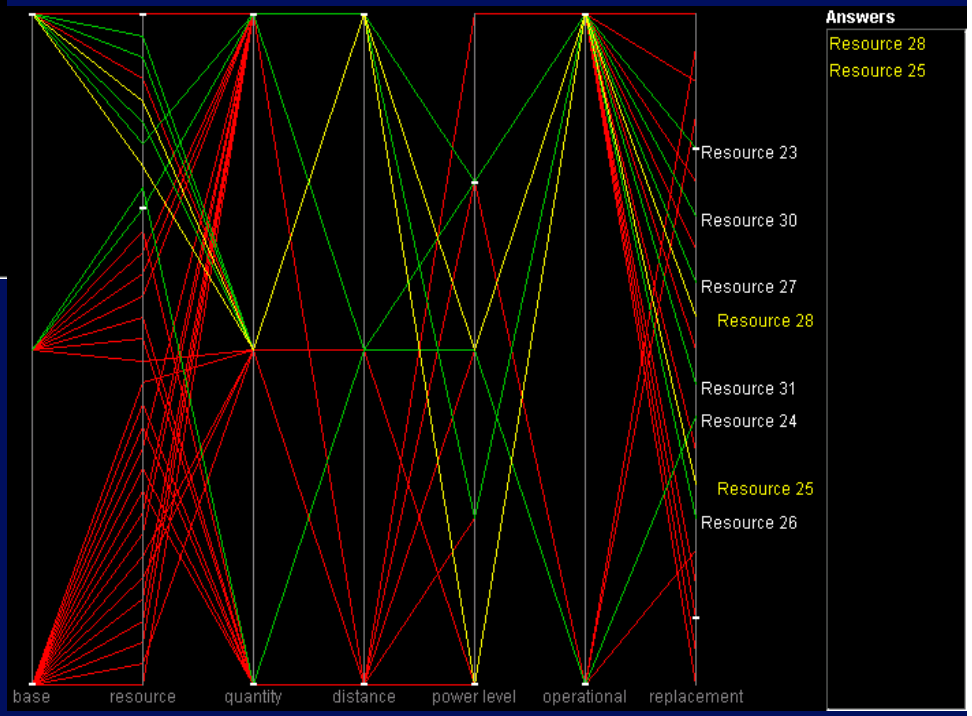
Wow Vis

Just-a-Vis



Parallel co-ordinates

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Experiment 2

- Simple Tasks
- Complex Tasks
- Visualisation (chosen from Experiment 1) compared to databases and graphs
- Differing data densities

Conclusions

- Technological advances = battlefield intelligence assets that can generate vast amounts of real time information
- Visualisation is the key to realising the potential of that information
- Designing visualisations appropriately is essential

Questions?

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